

The Measurement of Incomplete Charge Collection in a Si(Li) Detector using a Monochromatic Soft X-ray Beam below 1 keV.

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Beamline(s): U7A

Introduction: The fluorescence detection and measurement of characteristic X-rays employing semiconductor detectors is an important technique for element analysis of materials and surfaces. Both lithium-drifted silicon, Si(Li), and high-purity germanium, HPGe, detectors operated at cryogenic temperatures are commonly used for X-ray fluorescence applications. However, the detection efficiency of both types of detector is limited at X-ray energies below 1 keV due to absorption by material layers in front of the active detector material and an intrinsic dead-layer of semiconductor material that varies with the strength of the electric field at the front contact of the detector. The characteristic X-rays of the lightest elements, including Oxygen, Nitrogen, Carbon, Boron and Beryllium, which are of fundamental importance to materials research, lie in the affected energy range. Future progress in quantitative low-Z element analysis therefore requires improved detector performance with adequate sensitivity and energy resolution.

Methods and Materials: One important technique for characterizing the low energy sensitivity of a semiconductor X-ray detector is to measure the ratio of events collected in the full photon peak compared to those appearing at lower energies in the spectrum, for a given monochromatic energy. The present experiment attempts to develop a technique for directly measuring the magnitude of these lower energy events, termed Incomplete Charge Collection or ICC, in a Si(Li) detector as a function of monochromatic incident energy below 1 keV.

Measurements were performed on the U7A beam-line at the NSLS with the goal of measuring the detection efficiency as a function of photon energy, to determine the correlation of dead-layer thickness with spectral characteristics. The beam-line provides a high-intensity, monochromatic photon source that is tunable in the energy range from 0.2 to 1.1 keV and thus an ideal source for high-sensitivity X-ray fluorescence measurements at low energies. A windowless prototype detector incorporating a 10 sqmm Si(Li) crystal was installed at the end of the beam-line to measure primary beam photons directly. Such direct measurements in the high-intensity photon beam were possible by attenuation of the primary beam intensity by several orders of magnitude using photons from the beam periphery. A suitable count rate of approximately 2000 counts per second was achieved by adjustment of the beam. Data was collected at photon beam energies between 300 and 900 eV.

Results: The resulting energy spectra showed the expected plateau from the incomplete charge collection at energies below the beam's monochromatic peak. Figure 1 shows the spectrum at 400 eV beam energy, which clearly demonstrates the flat incomplete charge collection plateau in the energy range between about 140 eV and 260 eV. The edge below 140 eV indicates the count roll-off due to the programmed digitization threshold. The peak at 400 eV is the signal from the primary photon beam, and the peaks at 800 eV and 1200 eV are signals from the beam harmonics. Preliminary analysis of the data for all measured photon beam energies confirms the general trend of the peak-to-background versus energy dependence expected for improved low-energy detector sensitivity. However, the detailed functional dependence is not completely monotonous, which suggests the additional influence of an external factor, most likely caused by scattered photons from the beam-line. Indeed, the spectra observed during this beam-time improved as the beam was more tightly collimated.

Conclusions: The data collected represents the first experimental measurements of incomplete charge collection effects from monochromatic X-rays below 1 keV. These measurements will thus provide a benchmark for detector crystals fabricated from further improved processes with reduced dead-layer. Ultimately, this type of information will form the basis of a future model to predict the low-energy performance resulting from different fabrication processes.

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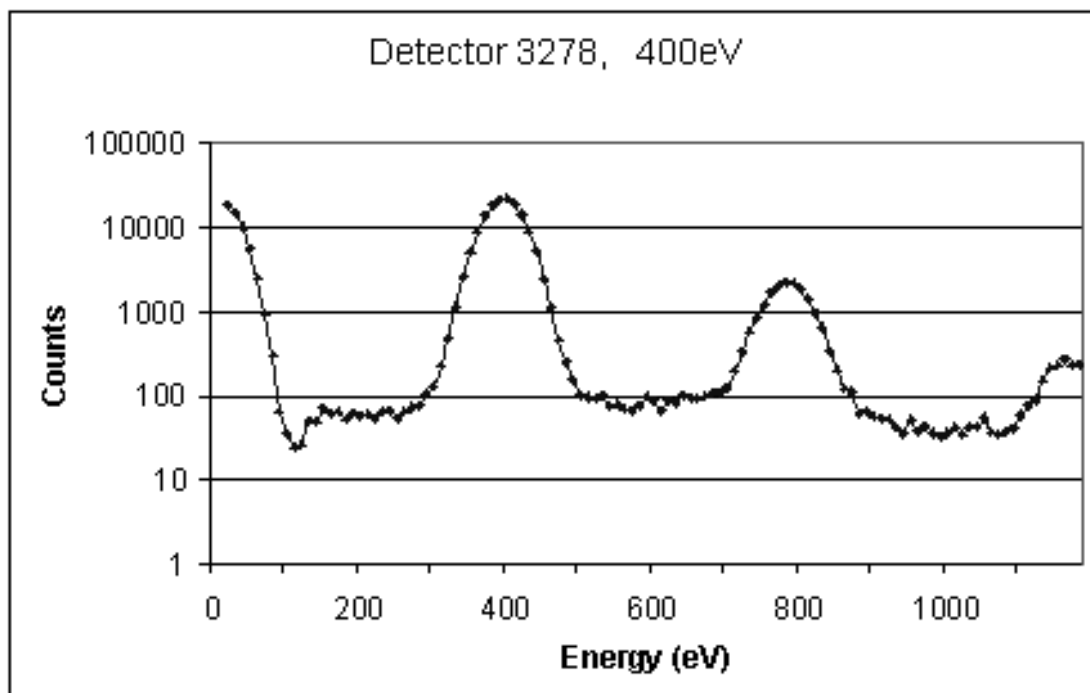


Figure 1. Energy spectrum from detector #3278 installed on U7A with 400 eV incident energy.